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TREATMENT AND DISPOSAL OPTION

CHAPTER 4

TREATMENT AND DISPOSAL OPTIONS

1. GENERAL PHILOSOPHY

Medical waste is heterogeneous in nature and may contain a diverse range of materials, such as paper, plastics, pathological wastes, animal carcasses, blood-soaked bandages, syringes, scalpels, and many other materials. The major items of concern are pathogens, cytotoxic chemicals, hazardous chemicals, and radioactive materials. Because of this heterogeneous composition, not all treatment and disposal techniques are effective in the destruction process.

There is a clear distinction between waste treatment and waste disposal. In the treatment process, the major objectives are to reduce the toxic nature of the waste, to change the waste into a physical form that is easier to manage, or to reduce the volume of the waste. Waste disposal refers to the final step where the waste is taken out of contact with the environment.

2. MANAGEMENT OPTIONS

2.1 INCINERATION

The most common means of treatment of bulk medical waste is incineration. The process effectively renders the waste non-infectious and unrecognisable as medical waste. Incineration can be used to treat the entire spectrum of medical waste. It reduces the volume as well as the weight of waste, leaving only a small quantity of ash to dispose of.

Medical waste has always been considered more hazardous than household wastes, because of its infectious nature. The process of incineration destroys bacteria and viruses that are responsible for infection very efficiently. The bulk of waste however consists of materials other than pathogens, and incineration also has to destroy these heterogeneous compositions. It is in this process that acid gases are formed (from the chlorinated plastics), toxic metals may be released (from the pigments and additives in paper and plastic products, as well as from discarded batteries and mercury thermometers), and dioxins and furans may be produced (from chlorinated materials in the waste). Over many years, the potential hazards associated with medical waste incineration have been the subject of many studies and considerable controversy. In response to these concerns, incinerator technologies and emission control systems have improved significantly over the past decade. More stringent regulatory control introduced in the USA and certain countries in Europe, primarily based on the firm enforcement of health-based criteria, has made it possible today for the technology to be applied without detrimental effects to community health and the environment. Current incinerator designs and emission control technologies make the strict regulation of performance feasible [Van Niekerk, 1994].

Techniques of medical waste incineration are discussed in more detail in Part 2, Chapter 1.

2.2 MICROWAVING

In the microwaving process, infectious waste is exposed to high-temperature steam, shredded, and then heated by a series of microwave generators for a specified period. Micro-organisms are killed in the process, and the waste is changed into a confetti-like, slightly moist residue.

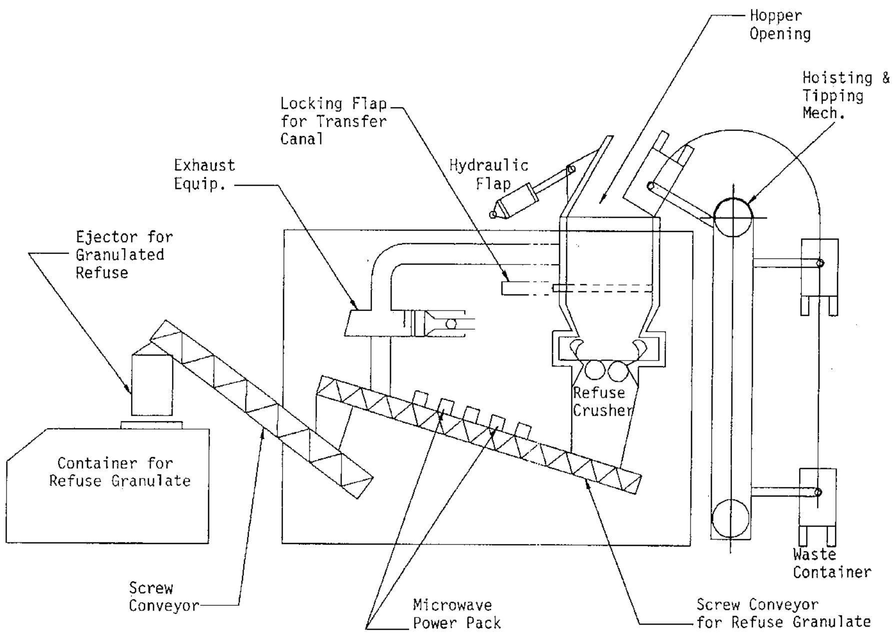

Figure 4.1: A typical microwave waste treatment unit

A commercial system has been developed in the USA to treat such items as sharps, pathological waste, microbiological materials, blood, and biological fluids. It is not suitable for the treatment of anatomical, chemically-hazardous, or radioactive wastes. Figure 4.1 illustrates the components of a typical microwave treatment facility [Cross *et al*, 1990].

2.3 AUTOCLAVING

Small steam decontamination systems are used widely in health care facilities for the sterilisation of equipment, but large units for medical waste treatment are uncommon. A self-contained autoclave for medical waste treatment has been developed by Sani-1-Pak in the USA, and there may also be other models. The waste is exposed to high-temperature steam in a closed, evacuated chamber, heating the waste to temperatures of 135 to 138 EC. After the required treatment period, the built-up steam is routed through a condensate tank to remove odours. The waste is then shredded and compacted for disposal, normally in a municipal solid waste landfill. Figure 4.2 illustrates the components and loading of an autoclave [Cross *et al*, 1990].

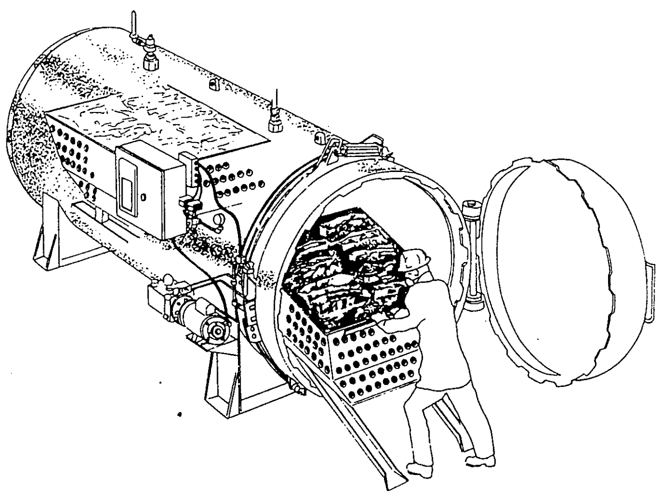

Figure 4.2: A typical autoclave used for sterilisation of medical waste

Autoclaving is effective to kill microorganisms, but cannot destroy radioactive, chemotherapy, or hazardous substances. It is also not suitable to handle contaminated animal carcasses, human body parts, or pathology wastes. Autoclaving is an attractive technique to employ in recycling of glass and metal items. It may also be useful as a pre-treatment process in countries where landfill space is a minor problem, and scavengers are not operating at the disposal sites. Further autoclaving can also be used for pre-treatment of medical waste before it is processed in a municipal solid waste incinerator.

2.4 ELECTRO-THERMAL DEACTIVATION

The process involves shredding of waste, loading into special containers, and heating with low frequency radio waves for a period that is adequate to destroy microorganisms. The technology requires a large warehouse, shredders, conveyors, and a specially designed dielectric furnace. To optimise use of the facility, waste is segregated and some items are processed separately. The waste is exposed to a high-intensity, oscillating electric field generated by low frequency radio waves (14 MHz). Heating is caused by absorption of the electrical energy. Composition of the treated waste is identical to the original materials, except that it is shredded and disinfected. The technique is not effective in treating radioactive, chemotherapy or hazardous substances. It is also not suitable to handle contaminated animal carcasses and human body parts.

2.5 CHEMICAL/MECHANICAL

A chemical/mechanical system disinfects shredded wastes through treatment with a solution containing chlorinated or other chemical compounds. Systems are typically closed, designed to re-circulate the treatment solution. The waste is changed to a moistened, solid residue. Effluent systems produce a large volume of water containing the depleted chemicals. The process is also known as hydropulping.

Figure 4.3 illustrates the essential steps of the process [Cross *et al*, 1990].

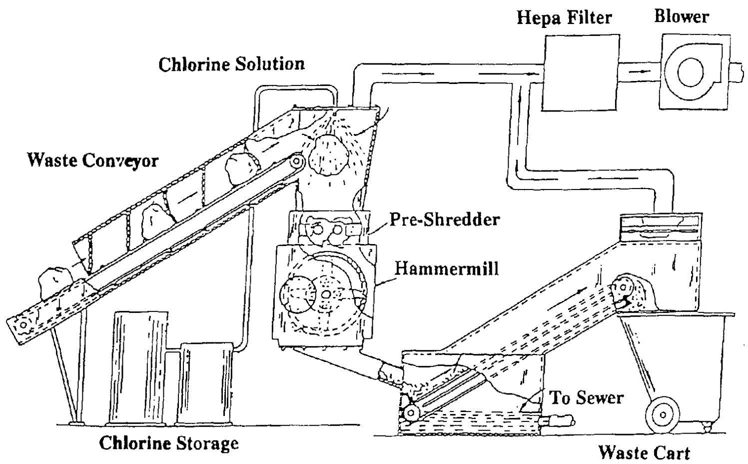

Figure 4.3: The mechanical/chemical waste treatment procedure

The infectious waste is received onto an enclosed conveyor and transported to a feed hopper where it is sprayed with a disinfectant chemical. The waste and disinfectant then go through a shredder and a high-speed hammer mill. The resulting slurry is fed from a separating tank where final contact with the disinfectant is achieved, to a separating conveyor. The solid waste is deposited into a cart for removal to a municipal landfill, and the liquid is discharged into the sewer system.

The entire system is kept under negative pressure, to prevent contamination of ambient air with infectious gases or aerosols, and the air is discharged through a HEPA filter.

The process cannot treat radioactive, chemotherapy or hazardous substances. It can also not handle substances that are incompatible with the sewer system, large cloth items such as sheets, certain metal objects, volatile or flammable substances, and materials that are incompatible with chlorine. The major limitations are related to problems with effective separation of wastes. Plastics, cloth, metal objects, and glass cause equipment wear and have to be separated prior to pulping. Separation of hospital wastes may in some cases be a limiting factor, because of difficulties in effective sorting.

2.6 GAMMA-RADIATION STERILISATION

Sterilisation of medical items using gamma rays is an established commercial technique. In principle, γ-ray treatment is suitable for sterilisation of medical waste, but although it has been investigated as an option, it has not been implemented on a commercial scale. The fact that it is essentially a sterilisation unit, it cannot treat all types of medical wastes in preparation for disposal, and it requires an expensive infrastructure.

The radiation source is normally cobalt-60, installed in a water-pool facility, with the waste transported to the treatment zone through a concrete labyrinth, designed for shielding of workers in the loading area. During treatment, the cobalt source is hoisted from the pool, exposing the waste on the slow-moving conveyors for a required time. The water in the pool acts as a shield for the γ-rays when the facility is not in operation. In Figure 4.4, the top drawing shows the facility in operation, while the lower part illustrates the Arest@ or maintenance position [Cross *et al*, 1990].

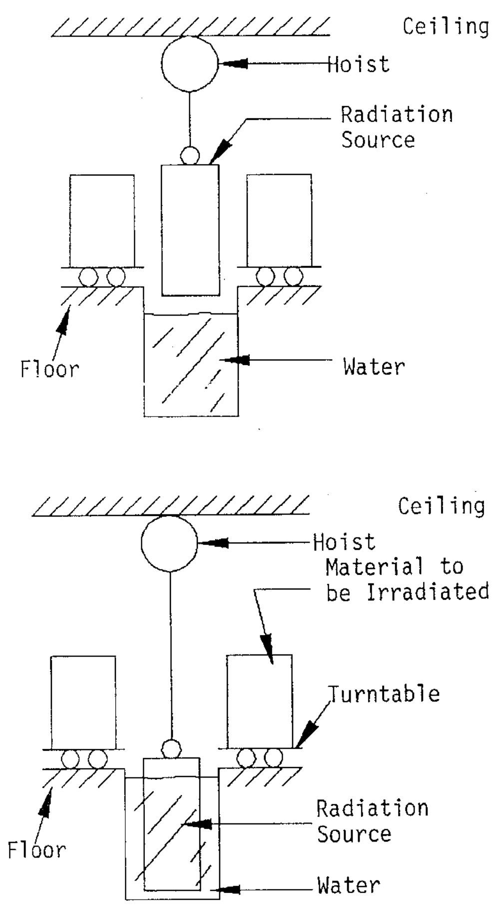

Figure 4.4: Diagram of a gamma irradiation facility

2.7 EMERGING TECHNOLOGIES

2.7.1 Molten salt technology

The technique has been in existence for many years in chemical processing, but only in recent years has it been investigated for the destruction of hazardous wastes

[Theodore, 1990]. In this process, combustible waste and air are injected into a bath of molten salt, below the surface. The combustible constituents are destroyed, and hazardous metals trapped in the salt. These can be disposed of as inert, solidified waste with great reduction in volume. The process is ideally suited for the treatment of small-volume highly hazardous wastes. It is operated at temperatures of typically above 800 EC, requiring containers made of ceramics or special steels. The major limitation of the technique lies in its small capacity, both from a practical and financial point of view.

2.7.2 Plasma systems

The generation of high-temperature plasmas is an established technique in the minerals and metals processing industries. The process has been developed in recent years for the destruction of hazardous wastes, and several pilot-plant and full-scale systems are in operation in the world.

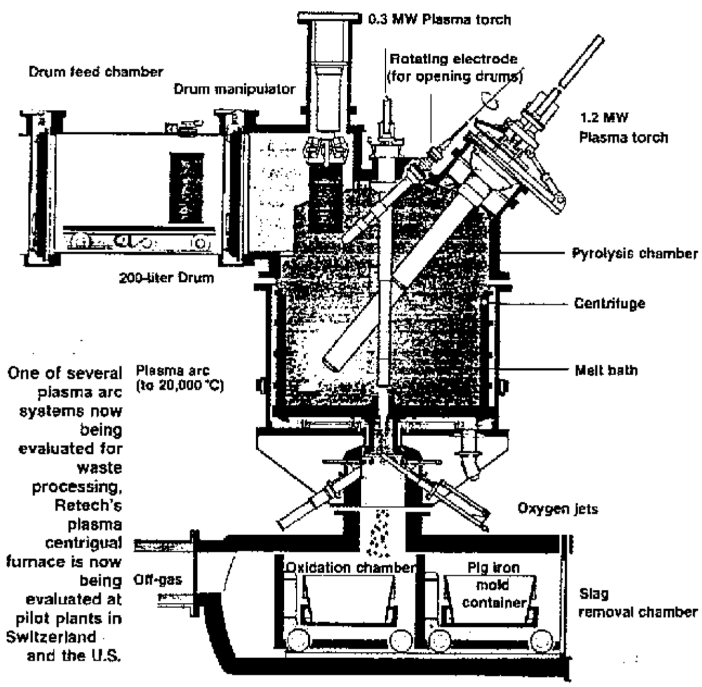

Figure 4.5: A plasma waste destruction facility [Ondrey G and Fouhy K, 1991]

Plasmas are generated by electrical discharge in gas, either between high-voltage electrodes, or induced by microwave or radio radiation. The pressure of the gas determines the temperature and transport properties of a plasma. With core temperatures of up to 10 000 EC, plasmas break down toxic compounds in milliseconds, avoiding the formation of secondary products of combustion (incomplete combustion). Flue gas cleanup is simplified, effectively limited to scrubbing for removal of acids. The achievement of ultra-high temperatures has also provided the opportunity for development of a vitrification-pyrolysis process for treatment of heterogeneous wastes. While organic materials are destroyed into their atomic constituents, heavy metals are immobilised in the vitrification process. This produces a glassy, non-leachable slag.

Plasma waste destruction is undoubtedly the most advanced thermal treatment process for hazardous wastes, including medical wastes. Although standard units may not be available, it can be expected that more and more systems built for specific applications and capacities will be installed for waste destruction around the world.

3. COMPARISON OF TREATMENT TECHNOLOGIES

Table 4.1 summarises some of the important characteristics of the major technologies available for medical waste treatment [Borowsky A R and Fleischauer P D, 1993].

As indicated, incineration and plasma waste destruction are the only technologies capable of treating the full range of medical wastes that can be generated by health care facilities, pharmaceutical companies, medical research laboratories, and pathology laboratories. Although effective for the treatment of certain types of wastes, the other techniques cannot handle a complete waste stream without sorting of the waste. Applications are therefore limited, and focused on activities where only certain types of wastes or recyclable items require treatment. With more focus on effective sorting of waste and recycling, however, some of the alternative technologies may be attractive.

Waste reduction is achieved with all the techniques. Incineration and plasma destruction convert the waste to relatively small amounts of ash that have to be disposed of, while wastes treated in other processes can be compacted, thereby also achieving this objective. Molten salt technology is a destructive technique, with the ability to reduce waste volumes considerably. It is virtually only the toxic metals that remain trapped in the salt. It should be kept in mind, however, that the capacity of this technique is small.

Noise and odours are factors to take into consideration. Conveyor belts, air blowers and extraction fans, compressors, shredders, and compactors, all add to noise levels above background. Noise is a factor to take into account from an occupational exposure point of view, and also in selecting the location of a facility where communities may be affected. All the treatment facilities have the potential to release odours to the environment. In some cases the potential for odour releases is limited to fugitive emissions from the untreated wastes, for example with plasma destruction. In general, facilities must be operated within the limitations of the waste types for which they are effective, and odour control systems must be in place where required.

Table 4.1 lists characteristics of treatment alternatives. Some of the data were taken from work published by Borowsky and Fleischauer [1993]. In cases where shredding and compaction are the techniques for achieving waste reduction, as for microwaving, autoclaving, electro-thermal deactivation and chemical/mechanical treatment, waste reduction has been quoted to vary from 80 per cent to over 85 per cent for the different techniques. It is not clear how reliable these volume reduction figures are. A general statement that waste reduction of 80 per cent or more can be achieved with compaction may be preferable. Noise levels listed in the table should also be interpreted as provisional, because noise depends on specific design features of the different technologies, plant layout, and building design.

Terms used in Table 4.1 to describe relative acceptability are as follows:

- *Acceptable* indicates that the technique can be used on a routine basis for the treatment of the particular type of waste, and that such process operating within its specifications would not cause harm to employees, communities, or the environment. The waste can also not damage components of the facility.

- *Unacceptable* indicates that the technique should not be used for the treatment of the particular type of waste, because it may pose health risks to employees and the public because of ineffectiveness or other hazards. The process may also be unacceptable because specific waste constituents may damage components of the installation.

- *Limitations on acceptability* means that the technique can be used only under certain conditions. Waste separation may be required in some cases to remove unacceptable waste components, or the technique can handle only small quantities of a particular waste type without detrimental consequences to human health and the environment.

Table 4.2 lists features that are pertinent for technology selection. The table indicates where techniques offer advantages, and where disadvantages should be considered. In some cases, features do not provide any advantages, but are not negative in terms of the overall assessment. Data are not quantifiable, because different designs of equipment may have different performance characteristics. For example, air emissions are indicated as a negative aspect of incineration. The problem can be overcome, however, by using good incineration technologies and post-combustion control devices. Limitations on the acceptability of a technique for certain waste types, on the other hand, may rule out the suitability of the technique for treatment of that range of waste types.

Incineration and plasma destruction have the biggest advantage in volume reduction, and are the only technologies that can handle the entire heterogeneous waste streams classified as :medical waste. The potential for air emissions, cost of treatment, and public concerns, are undesirable aspects that have to be considered.

It is not the purpose of this review to elaborate on each item for the various treatment options, but to highlight those features that have to be considered in the selection of the most appropriate technique for a particular application. The table may also serve as a guideline to list features that have to be clarified when the potential impacts of a facility are considered, and when specialist studies are required to confirm the acceptability of a proposed facility.

Table 4.1: Characteristics of waste treatment techniques

CHARACTERISTICS Acceptable waste type	INCINERATOR	MICROWAVE	AUTOCLAVE	ELECTRO-THERMAL	CHEMICAL/ MECHANICAL	γRADIATION	MOLTEN SALTS	PLASMA SYSTEMS
Υ : acceptable		Ψ: unacceptable		ΥΨ: limitations on acceptability			: not specified	
Pathological	Υ	Ψ	Ψ	Ψ	ΥΨ	ΥΨ	ΥΨ	Υ
Radioactive	ΥΨ	Ψ	Ψ	Ψ	Ψ	Ψ	ΥΨ	Υ
Chemotherapy	Υ	Ψ	Ψ	ΥΨ	ΥΨ	Ψ	Υ	Υ
Liquid	Υ	ΥΨ	Ψ	Υ	ΥΨ	Υ	Υ	Υ
Metals/sharps	Υ	ΥΨ	Υ	ΥΨ	ΥΨ	Υ	Υ	Υ
Paper	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ
Plastic	Υ	Υ	Υ	Υ	ΥΨ	Υ	Υ	Υ
Lab trash	Υ	Υ	Υ	Υ	ΥΨ	Υ	Υ	Υ
Infectious	Υ	Υ	Υ	Υ	Υ	Υ	Υ	Υ
Animal waste	Υ	Ψ	Ψ	Ψ	Ψ	ΥΨ	Ψ	Υ
Volume reduction	∃85 %	80 % (compaction)	80 % (compaction)	85 % (compaction)	∃85 % (compaction)	∃80 % (compaction)		∃85 %
Noise	100 db	65 db			80 - 100 db			
Odour	Υ	Υ	Υ		Υ	Υ	Υ	Υ

Table 4.2: Features to consider in selecting medical waste treatment techniques

⎫: indicates advantage or desirable aspect | : indicates disadvantage or undesirable aspect □: indicates neutrality

FEATURE	INCINERATOR	MICROWAVE	AUTOCLAVE	ELECTRO-THERMAL	CHEMICAL/ MECHANICAL	γRADIATION	MOLTEN SALTS	PLASMA SYSTEMS
Volume reduction	⎫	⎫	⎫	⎫	□	□	⎫	⎫
Air emissions	|	□	□	□	|	□	|	|
Liquid discharge	⎫	⎫	|	|	|	⎫	⎫	⎫
Decontamination/ sterilisation	⎫	□	⎫	⎫	|	⎫	⎫	⎫
Recycling/reuse	□	⎫	□	⎫	⎫	□	□	□
Acceptable waste types	⎫	|	|	|	|	|	|	□
Cost of treatment	|	□	⎫	|	⎫	|	|	|
Capacity	⎫	□	□	□	⎫	⎫	□	⎫
Public concern	|	□	□	□	|	|	□	|

4. SUMMARY OF TREATMENT, TRANSPORT, AND DISPOSAL ALTERNATIVES FOR HOSPITAL WASTES

Table 4.3 lists various types of wastes and the most popular alternatives for collection, storage, treatment, transport, and disposal of hospital wastes. Waste is generally collected in colour-coded plastic bags, eg red bags for infectious waste. The waste is then transported for internal or external processing.

The table shows how specific types of items may be handled in practice. The treatment method preferred by most hospitals is incineration. Where incineration is mentioned, plasma destruction may also be used. It is normally preferred to handle pathological waste on site, but off-site treatment is also practiced. In such cases the waste is sealed in red bags, put into boxes that are sealed, and transported to an off-site incinerator. It is preferable that waste is sterilised on site prior to transporting to the off-site incinerator.

The liquid part of kitchen waste is discharged directly into the sewer system, while solids are handled as normal domestic waste. Some components of administrative wastes, mostly paper, and uncontaminated boxes, cans, and bottles, can be recycled.

Autoclaving, microwaves, and other techniques are very rarely used as treatment option for medical waste. Incineration is by far the most common technique used in developed countries. Hospitals may consider two alternatives for the disposal of hazardous waste. Solvents and other hazardous wastes can be identified and placed in suitable packs for shipment to a hazardous waste disposal facility. Centralised incinerators are economically attractive for treatment of infectious waste, and it is an option to use centralised medical waste incinerators to handle all hospital waste. Figure 4.6 illustrates a possible scheme for the management of hospital wastes [Dross F L and Robinson R, 1988].

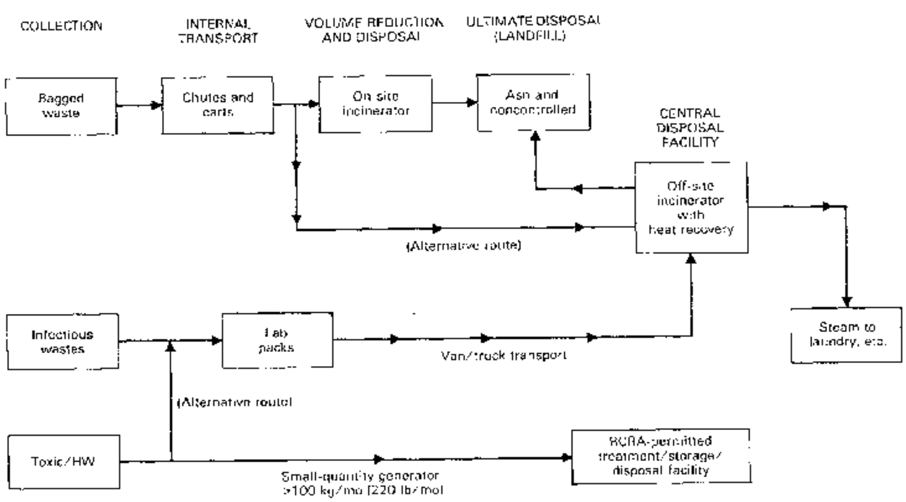

Figure 4.6: A possible scheme for hospital waste managemen

Table 4.3: Summary of alternative methods for collection, treatment, storage, transport and disposal of hospital wastes

WASTE TYPE	PROCESSING ALTERNATIVES																					
	STORAGE					TRANSPORT					VOLUME REDUCTION (ON-SITE)			DISINFECTION TECHNIQUES						DISPOSAL		
	INTERNAL			EXTERNAL		INTERNAL				EXTERNAL				ON-SITE				OFF-SITE				
	Red bags	White bags	Sharps container	Loose in container	Compactor	Carts	Hydraulically	Pneumatically	Chutes	Trucks	Incineration	Compaction	Wet pulping	Sterilisation	Incineration	Irradiation	Chemical disinfection	Incineration	Sterilisation	Sanitary landfill	Incineration	Recycle
Pathological wastes	Y					Y			Y		Y			Y	Y	Y	Y	Y				
Infectious wastes	Y					Y	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y	Y		Y	
Administrative wastes		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y					Y		Y	Y	Y
Boxes		Y		Y		Y				Y	Y	Y	Y					Y		Y	Y	Y
Kitchen wastes		Y		Y		Y	Y			Y			Y							Y	Y	
Cans				Y	Y	Y				Y		Y								Y		Y
Bottles				Y	Y	Y				Y		Y		Y		Y				Y		Y
Syringes and medicines			Y		Y									Y	Y	Y		Y		Y	Y	

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